A Preliminary Analysis of the Discreteness of Stocks of Walleye Pollock *(Theragra chalcogramma)* From the Northeastern Pacific Ocean Off Canada Based on Their Parasites

J. R. Arthur

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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RÉSUMÉ

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L'auteur a appliqué à des données sur les parasites les méthodes statistiques d'analyse typologique afin d'étudier la ségrégation des stocks des morues du Pacifique occidental capturées à quatre endroits en Colombie-Britannique (le détroit de Géorgie, la côte ouest de l'île Vancouver, le bassin Reine-Charlotte et l'entrée Dixon). Des treize espèces de parasite utilisées pour classer chaque poisson selon son origine géographique, quatre (Rhipidocotyle sp., métacercaire; Nybelinia surmenicola Okada in Dollfus, 1929, plérocercoide, Anisakis simplex (Rudolphi, 1809), larve; et Prosorhynchus sp., métacercaire) se sont révélées les plus utiles pour séparer les catégories. L'évaluation des modèles de classification à l'aide de trois méthodes qui affectent chaque poisson à une catégorie de classement (l'analyse discriminante linéaire de catégories complexes, l'analyse-k du plus proche voisin et la classification bayesienne)* a généré des pourcentages relativement bas de classement général correct (<50 %). Un pourcentage relativement élévé de classement (>75%) correct n'a été obtenu que pour les morues du détroit de Géorgie. D'autres analyses statistiques complétées par des observations sur la présence de larves de type Contracaecaum et de métacercaires du genre Prosorhynchus dans les quatre zones échantillonnées portent a croire que les stocks de morue du Pacifique occidental du détroit de Géorgie et de la côte ouest de l'île Vancouver sont relativement isolés l'un de l'autre et des poissons peuplant les deux zones septentrionales (le bassin Reine-Charlotte et l'entrée Dixon). On n'a noté aucune différence chez les parasites observés dans les échantillons recueillis à l'intérieur de ces deux dernières régions.

Mots-clés: morue du Pacifique occidental, Theragra chalcogramma, parasites, identification de stocks, analyse typologique, Colombie-Britannique.

Page iii - (50%) becomes (<50%) and (75%) becomes (>75%).

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A PRELIMINARY ANALYSIS OF THE DISCRETENESS OF STOCKS OF WALLEYE POLLOCK (*Theragra chalcogramma*) FROM THE NORTHEASTERN PACIFIC OCEAN OFF CANADA BASED ON THEIR PARASITES

June 1983

by

J. R. Arthur[1]

Department of Fisheries and Oceans

Fisheries Research Branch

Pacific Biological Station

Nanaimo, B.C., Canada V9R 5K6

[1]Present Address: E.V.S. Consultants Ltd.
Box 8, Marine Technology Centre,
9865 West Saanich Road
Sidney, B.C. Canada
V8L 3S1

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ABSTRACT

Arthur, J. R. 1983. A preliminary analysis of the discreteness of stocks of walleye pollock (Theragra chalcogramma) from the northeastern Pacific Ocean off Canada based on their parasites. Can. Tech. Rep. Fish. Aquat. Sci. 1184: iv + 15 p.

The statistical techniques of pattern recognition were applied to parasitological data to investigate the discreteness of walleye pollock stocks collected from four British Columbian localities (Strait of Georgia, west coast of Vancouver Island, Queen Charlotte Sound, and Dixon Entrance). Of the thirteen species of parasites used to assign individual fish to their area of geographic origin, four species (Rhipidocotyle sp. metacercaria; Nybelinia surmenicola Okada in Dollfus, 1929 plerocercoid; Anisakis simplex (Rudolphi, 1809) larva; and Prosorhynchus sp. metacercaria) contributed most to category separation. Evaluation of classification models using three methods that assign individual fish to a classification category (multicategory linear discriminant analysis, k-nearest neighbor analysis, and Bayesian classification) gave relatively low percentages of overall correct classification (50%). A relatively high percentage of correct classification (75%) was achieved only for pollock from the Strait of Georgia. Additional statistical analyses complemented by observations on the occurrence of Contracaecum-type larva and Prosorhynchus sp. metacercaria within the four sampled areas indicate that stocks of walleye pollock from the Strait of Georgia and the west coast of Vancouver Island are relatively discrete from each other and from fish from the two northern areas (Queen Charlotte Sound and Dixon Entrance). No parasitological differences were observed between samples from the latter two areas.

Key words: Walleye pollock, Theragra chalcogramma, parasites, stock identification, pattern recognition, British Columbia.

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Mots-clés: morue du Pacifique occidental, Theragra chalcogramma, parasites, identification de stocks, analyse typologique, Colombie-Britannique.

INTRODUCTION

The walleye pollock (Theragra chalcogramma (Pallas)), one of the most abundant species of fishes occurring in the North Pacific Ocean, has recently gained increased recognition as a marine resource of great economic potential for the Canadian fishing industry (see Thompson 1981). Of primary importance for successful management of the fishery and prevention of over exploitation of the resource is an understanding of the life history of the walleye pollock and, in particular, knowledge of the distribution and distinctness of pollock stocks.

Few previous studies have provided information on the discreteness of stocks of walleye pollock in North American waters. Wilimovsky et al. (1967), using meristic and morphometric measurements, investigated pollock collected from the waters of Puget Sound northward to the Bering Sea. Although clinal trends in fin ray and vertebral counts were observed, these authors found no strong evidence for discrete races or stocks. In a biochemical analysis of genetic variation in enzymatic proteins, Grant and Utter (1980) concluded that no distinct stocks of walleye pollock occurred within the Gulf of Alaska nor within the southeastern Bering Sea. However, small but distinct biochemical differences were noted between collections of fish taken from these two areas. Japanese workers (Iwata 1975a, b; Hashimoto and Koyachi 1977; Koyachi and Hashimoto 1977) using meristic, morphometric, and biochemical data have postulated the existance of separate sub-populations of walleye pollock in the eastern Bering Sea, in the Gulf of Alaska, and along the west coast of Canada and have also suggested that pollock occurring off North America may be discrete from those occurring in Asian waters. In general, although migration and straying may take place, it appears that pollock tend to occur and spawn in characteristic regions of the continental shelf where these "local forms" or "sub-populations" are exploited by local fisheries (see for example Hashimoto and Koyachi 1969, 1977; Takahashi and Yamaguchi 1972; Maeda 1972; Tsuji 1972; Iwata 1975b, Serobaba 1977; Koyachi and Hashimoto 1977; Grant and Utter 1980).

For management purposes the initial definition of Canadian walleye pollock stocks was derived from the geographically discrete distribution of the fishery. Major fisheries have occurred in Dixon Entrance and the Strait of Georgia, with minor fisheries occurring in southern Hecate Strait, Queen Charlotte Sound, and off the west coast of Vancouver Island. Subsequent evidence for the distinctiveness of these stocks has been provided by growth rate studies and the observation of relatively discrete spawning areas (Ketchen 1980; Thompson 1981).

Analysis of the parasite fauna of marine fishes has often proved useful in providing fisheries management with an auxiliary source of information on the biology, migrations, and discreteness of host populations (see for example Margolis 1963, 1965; Kabata 1967; MacKenzie and Johnston 1976; Arthur and Arai 1980). The present study, part of a comprehensive investigation of the parasite fauna of walleye pollock, was undertaken to provide a preliminary analysis of the usefulness of parasites as biological indicators for stocks of walleye pollock occurring in Canadian waters.

Additional reports (Arthur et al. 1982; Arthur 1983) present detailed results of a parasitological survey of Canadian walleye pollock and provide an analysis of the effects of post-mortem handling on the abundance of parasites in the musculature.

MATERIALS AND METHODS

HOST COLLECTIONS

Walleye pollock were collected during the period September 1978-September 1979 from four British Columbian localities. Pollock from Swanson Channel (Strait of Georgia), collected by bottom trawl, were obtained from the commercial fishing vessel M/V ANDONIS. All other hosts were collected by midwater or bottom trawl by the Sechelt Indian Band's vessel ARCTIC HARVESTER, on charter to the Pacific Biological Station. Gills were removed from pollock collected from Queen Charlotte Sound and Dixon Entrance, immersed in hot water to kill attached parasites, and preserved in 5% formalin. All hosts were frozen in the round for storage prior to examination for parasites. As previous investigations (Arthur et al. 1982) have shown that host sex may be a significant factor in determining parasite abundances, only female fish were included in the present analyses. Host data are given below with the following information presented for each collection: collection number, collection locality (see Fig. 1), date of collection (day, month, year), depth of collection (meters), number of fish examined, and their total length (range in cm followed by mean ± SD).

1. Swanson Channel, Strait of Georgia, B.C., 47°45'N × 123°20'W, 4/12/78, <200 m, n = 44, 44-61(50.5 ± 4.2)

2. West coast Vancouver Island, B.C., 48°24' - 49°16'N × 125°53' -126°12'W, 11-23/9/79, 205-274 m, n = 46, 46-71(53.6 ± 4.8)

3. Southeast Goose Island Grounds, Queen Charlotte Sound, B.C., 51°24'N × 129°15'W, 23-24/9/78, 190-198 m, n = 75, 52-73(60.5 ± 5.4)

4. Dixon Entrance, B.C., 54°15'N × 131°30'W, 25/9/78, 150 m, n = 38, 52-77(58.0 ± 4.2)

A detailed account of the methods of host examination and the treatment of parasites recovered is presented in Arthur (1983) along with a complete listing of all species recovered from the walleye pollock upon which this study is based.

STATISTICAL METHODS

Parasite data presented in Table 1 are expressed as prevalence (number of infected hosts/number of hosts examined, cited as a percentage), and abundance (mean number of parasites per host examined) as defined by Margolis et al. (1982). Because numbers of parasites recovered from all hosts (both infected and uninfected) were included in all statistical analyses the use of abundance rather than mean intensity (mean number of parasites per infected host) was considered more appropriate.

Because the distribution of parasite numbers was obviously non-normal, non-parametric statistical methods were used throughout the study. Analysis of collections for differences due to geographic locality was made using the Kruskal-Wallis test (see Sokal and Rohlf 1969). Sets of collections showing significant heterogeneity were further analysed by comparison of all combinations of pairs using the non-parametric simultaneous test procedure (STP test) as given in Sokal and Rohlf (1969). As the STP test requires that all collections to be compared be of equal sample size, when necessary, hosts were randomly deleted to acheive this criterion.

Analysis of the potential value of parasites in determining the stock affinities of individual fish and thereby serving as discriminators for stocks of walleye pollock was accomplished by the use of the techniques of pattern recognition contained in the computer package "Arthur"[1] (see Harper et al. 1977). A detailed discussion of these techniques and their application to the separation of fish stocks based on parasitological data is presented in Arthur and Arai (1980). Modifications of these techniques as applied in the present study are discussed below.

Preliminary studies (Thompson 1981) have shown that pollock from northern British Columbian waters grow more rapidly than those from southern areas. To minimize the possible influence of differential growth rates between pollock stocks on parasite abundance, hosts included in stock identification analyses were restricted to female fish whose lengths, based on known age-length relationships for northern and southern stocks, corresponded (within 95% confidence limits) to age class IV or greater (see Host collections). Attempts at stock separation were based on numbers or presence of 13 species of parasites whose infections in pollock were considered likely to be of sufficient duration to make them potentially useful as biological "tags". Definition of statistical terms used to describe the methods and results of pattern recognition techniques as applied to the separation of fish stocks are based on Harper et al. (1977) and are given in Arthur and Arai (1980). Initial evaluation of the usefulness of species of parasites as separators for pollock stocks (categories) was accomplished by examination of average Fisher weight values calculated from autoscaled parasite data. Feature selection and reduction was accomplished by Fisher-criterion transformation of autoscaled parasite data followed by autoscaling over all categories and Karhunen-Loeve transformation. Fisher-criterion transformation

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[1] Duewer, D. L., J. R. Koskinen, and B. R. Kowalski. "Arthur" available from B. R. Kowalski, Laboratory of Chemometrics, Department of Chemistry, University of Washington, Seattle, Washington.

seeks to optimize category-pair separation in as few variables as possible by producing a new set of features which are linear combinations of the autoscaled parasite data aligned along the best possible category-pair separation axes. For any n categories, there are n(n-1)/2 unique pairs of categories, and thus features, produced. Autoscaling and Karhunen-Loeve transformation of features obtained by Fisher-criterion transformation produced the minimum set of Fisher-criterion features, a set of n-1 (where n is the number of categories) uncorrelated features which contain almost all separation information contained in the original variables (see Kowalski 1974). Three methods of classification were used: multicategory linear discriminant analysis, k-nearest neighbor analysis (KNN), and Bayesian classification (see Harper et al. 1977; Arthur and Arai 1980). Evaluation of the classification ability (prediction) of the three methods was obtained by the random selection of a training set of equal numbers of data vectors (25) from each category and evaluation of the model constructed from the training set through the use of the remaining data vectors as an evaluation set (fish of known origin not used to construct the model). The sequence of random selection of a training set and its evaluation was repeated 10 times, the average percentage correct classification of the evaluation sets was then used as an estimate of the ability of the model to classify the data vectors correctly.

RESULTS AND DISCUSSION

Preliminary examination of the value of 13 species of parasites as potential category separators was based on decorrelated Fisher weight values calculated from autoscaled parasite data (Table 2). Relatively high average Fisher weights were obtained for three species (Rhipidocotyle sp. metacercaria; Nybelinia surmenicola Okada in Dollfus, 1929 plerocercoid; and Anisakis simplex (Rudolphi, 1809) larva); with three additional species giving somewhat lower values (Prosorhynchus sp. metacercaria; Contracaecum-type larva; and Abothrium gadi van Beneden, 1871).

Fisher-criterion transformation followed by autoscaling and Karhunen-Loeve transformation of autoscaled parasite data using 25 data vectors (fish)/category produced the minimum set of Fisher criterion features, a set of three new features which accounted for a total of 89.2% of the total variance contained in the original 13 variables. New feature 1 accounted for 54.3% of the total variance with features 2 and 3 accounting for 18.2% and 16.7%, respectively. A measure of the relative contribution of each of the original 13 features (parasite species) to the three new features is provided by their squared correlation (see Harper et al. 1977). Feature 1 had relatively high correlation with Rhipidocotyle sp., N. surmenicola, A. simplex, and Prosorhynchus sp., and smaller correlation with A. gadi and Spirurida larva (Table 3). Correlations of parasite species with features 2 and 3 were considerably lower than those obtained for feature 1, indicating that most of the separation information was contained in that feature. Major

components of feature 2 were Rhipidocotyle sp., A. simplex, and Contracaecum-type larva, while those for feature 3 were N. surmenicola, Grillotia heptanchi (Vaullegeard, 1899), and Prosorhynchoides basargini (Layman, 1930).

Results obtained from the classification of data vectors contained in the evaluation sets using three methods of analysis are presented in Table 4. Recognition (the ability to correctly classify data vectors contained in the training set) was highest for Bayesian classification (67.5 ± 5.4% correct); prediction (the ability to correctly classify data vectors contained in the evaluation set) was approximately equal (45.0 ± 4.0% - 48.7 ± 2.2%) for all three methods of classification. A misclassification matrix for results of prediction using one of the classification techniques (multicategory linear discriminant analysis) is presented in Table 5. Separation of the four categories was, in general, poor, with only data vectors from the Strait of Georgia (75.2 ± 13.9% correct classification) being relatively well classified. Misclassification of data vectors from each of the two southern collections was primarily to the other southern category; that for each of the two northern categories was primarily to the remaining northern category. Thus 44.8 ± 17.8% of data vectors representing fish from the west coast of Vancouver Island were correctly assigned with 41.9 ± 18.0% misclassified to the Strait of Georgia; 75.2 ± 13.9% of Strait of Georgia data vectors were correctly classified with 19.0 ± 12.9% misclassified to the west coast; 60.0 ± 23.0% of the data vectors representing fish from Dixon Entrance were correctly classified with 23.9 ± 16.7% misclassified to Queen Charlotte Sound; and 30.2 ± 20.4% of data vectors representing fish from Queen Charlotte Sound were correctly assigned with 40.6 ± 19.6% misclassified to Dixon Entrance. In general, data vectors representing pollock from northern and southern localities, with the exception of those from Queen Charlotte Sound, were not confused with each other. Of those data vectors representing pollock from Queen Charlotte Sound 15.2 ± 7.7% and 14.0 ± 10.2% were incorrectly assigned to the Strait of Georgia and the west coast of Vancouver Island categories, respectively. Although considerable differences exist in the prevalence of infection and abundance of parasites infecting walleye pollock stocks, the above results indicate that parasites cannot be used with confidence to assign individual pollock to their respective areas of geographical origin.

However, using different approaches, information on the discreteness of stocks of walleye pollock occurring off British Columbia can be obtained. These approaches involve comparison of the four collections of female pollock using the Kruskal-Wallis and STP tests and examination of the geographical distribution of certain parasite species in pollock. Using parasite prevalence and/or numbers, significant heterogeneity among collections was noted for ten of the 13 species of parasites (Table 6). Comparison of all combinations of category pairs using these ten species showed significant differences in all cases but one, no differences being noted for comparison of pollock from Dixon Entrance with those from Queen Charlotte Sound (Table 6). Pollock from both of these collections differed from those from the Strait of Georgia and the west coast of Vancouver Island in having greater prevalence and abundance of Prosorhynchus sp. metacercaria and greater abundance of Anisakis simplex larva. Pollock from both northern areas also differed from fish from the west coast of Vancouver Island in having lower prevalence of infection and/or abundance of Spirurida larva, and from fish from the Strait of Georgia in having lower prevalence of Rhipidocotyle sp. metacercaria, lower

prevalence and abundance of Abothrium gadi, and higher prevalence and abundance of N. surmenicola. Pollock from Dixon Entrance also differed from those from the west coast of Vancouver Island in having higher abundance of N. surmenicola and from both southern collections by having higher prevalence and/or abundance of Contracaecum-type larva. Comparison of pollock collected from the Strait of Georgia with those from the west coast of Vancouver Island revealed significant differences in only two cases. Prevalence of Rhipidocotyle sp. metacercaria was higher in fish from the Strait of Georgia than in those from the west coast of Vancouver Island while both prevalence and abundance of N. surmenicola were lower.

The geographical distribution of Prosorhynchus sp. metacercaria and Contracaecum-type larva provides additional evidence for the discreteness of walleye pollock stocks. Prosorhynchus sp. metacercaria occurred in approximately 60% of all fish examined from Queen Charlotte Sound, almost 100% of those taken from Dixon Entrance, and approximately 10% of all pollock examined from the west coast of Vancouver Island. Its apparent absence in walleye pollock from the Strait of Georgia would indicate that little or no immigration of adult fish from other areas to this stock occurs. Similarly, the presence of Contracaecum-type larva in over 40% of all fish examined from Dixon Entrance, in 20% of those examined from Queen Charlotte Sound, and in about 20% of all fish examined from the Strait of Georgia and its absence in walleye pollock from the west coast of Vancouver Island support the conclusion that little or no recruitment to the west coast of Vancouver Island stock from other areas occurs. Although the observed absence of parasitological differences between walleye pollock from Dixon Entrance and Queen Charlotte Sound may simply be the result of similar environmental conditions in the two areas, the possibility exists that only one stock of walleye pollock occurs off the eastern coast of the Queen Charlotte Islands.

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Table 1. Prevalence and abundance of parasites selected as potential biological indicators for walleye pollock from four British Columbia localities.

Parasite	Site[b]	Strait of Georgia (n=44) P(%) Abundance (range)[d]	West Coast Vancouver Island (n=46) P(%) Abundance (range)	Queen Charlotte Sound (n=75) P(%) Abundance (range)	Dixon Entrance (n=58) P(%) Abundance (range)
Protozoa					
Pleistophora sp.	musc	27.3	13.0	34.7	50.0
Digenea					
Aporocotyle theragrae	ba, bra	18.2 0.1≤0.5≤1.0(1-5)	30.4 0.4≤0.9≤1.4(1-7)	34.7 0.4≤ 0.7≤ 1.1(1-7)	15.8 0.0≤ 0.2≤ 0.3(1)
Prosorhynchoides basergini (m)[a]	fins		10.9 0.0≤0.8≤2.1(1-28)		2.6 0.0≤ 0.0≤ 0.1(1)
Prosorhynchus sp. (m)	fins[c]		8.7 0.0≤1.4≤4.0(1-58)	78.7 10.6≤17.9≤25.3(1-168)	97.4 9.8≤16.1≤22.5(1-103)
Rhipidocotyle sp. (m)	fins	95.5	63.0	25.3	23.7
Cestoda					
Abothrium gadi	pc, int	84.1 1.4≤2.4≤3.5(1-20)	52.2 0.5≤0.8≤1.2(1-4)	17.3 0.1≤ 0.2≤ 0.3(1-2)	36.8 0.3≤ 0.7≤ 1.1(1-5)
Grillotia heptanchi (p)	cc	6.8 0.0≤0.1≤0.1(1)	6.5 0.0≤0.1≤0.2(1-2)		
Nybelinia surmenicola (p)	bc, sw, mes, musc	43.2 0.4≤0.8≤1.3(1-9)	97.8 17.2≤23.9≤30.6 (1-112)	96.0 23.0≤44.8≤66.5(1-678)	100.0 38.7≤50.6≤62.4(2-141)
Nematoda					
Anisakis simplex (l)	bc, sw, mes, musc	97.7 20.1≤27.2≤34.2(3-104)	100.0 22.8≤26.2≤29.6(5-51)	100.0 55.9≤68.0≤80.2(8-269)	100.0 53.8≤65.2≤76.3(1-168)
Contracaecum type B (l)	mes	20.5 0.1≤ 0.3≤ 0.5(1-3)		25.3 0.2≤ 0.6≤ 0.1(1-11)	50.0 1.3≤ 2.5≤ 3.7(1-11)
Hysterothylacium aduncum (l)	mes	27.3 0.1≤ 0.7≤ 1.2(1-9)	58.7 0.7≤ 1.1≤ 1.5(1-5)	33.3 0.4≤ 0.8≤ 1.2(1-11)	52.6 0.8≤ 1.7≤ 2.6(1-15)
Phocanema decipiens (l)	musc	47.7 0.8≤ 1.2≤ 1.9(1-11)	32.6 0.2≤ 0.4≤ 0.6(1-4)	20.0 0.1≤ 0.3≤ 0.5(1-8)	26.3 0.1≤ 0.4≤ 0.7(1-4)
Spirurida gen. sp. type X (l)	iw, sw	15.9 0.0≤ 0.3≤ 0.5(1-4)	45.7 0.6≤ 1.1≤ 1.6(1-7)	6.7 0.0≤ 0.2≤ 0.4(1-7)	5.3 0.0≤ 0.1≤ 0.1(1)

[a] m = metacercaria, p = plerocercoid, l = larva

[b] ba = bulbus arteriosus, bc = body cavity, bra = branchial arteries, cc = cephalic canals, int = intestine, iw = intestinal wall, mes = mesenteries, musc = musculature, pc = pyloric caeca, sw = stomach wall

[c] rarely in cephalic canals, musculature, and on external surface of heart.

[d] Prevalence (percent infected), abundance ($\bar{x}$±95% confidence limits).

Table 2. Average Fisher weight values calculated from autoscaled parasite data.

Parasite	Fisher weight
Rhipidocotyle sp. (m)[a]	0.018
Nybelinia surmenicola (p)	0.014
Anisakis simplex (l)	0.011
Prosorhynchus sp. (m)	0.007
Contracaecum-type B (l)	0.006
Abothrium gadi	0.005
Spirurida gen. sp. (l)	0.003
Pleistophora sp.	0.002
Phocanema decipiens (l)	0.001
Aporocotyle theragrae	0.001
Hysterothylacium aduncum (l)	0.001
Grillotia heptanchi (p)	0.001
Prosorhynchoides basargini (m)	0.001

[a] m = metacercaria, p = plerocercoid, l = larva.

Table 3. Degree of correlation (C^2) between statistically transformed features and original parasite data.

Parasite	Feature 1	Feature 2	Feature 3
Rhipidocotyle sp. (m)[a]	0.462	0.183	0.028
Nybelinia surmenicola (p)	0.371	0.038	0.173
Anisakis simplex (l)	0.382	0.157	0.000
Prosorhynchus sp. (m)	0.342	0.023	0.065
Contracaecum-type B (l)	0.069	0.155	0.121
Abothrium gadi	0.265	0.002	0.018
Spirurida gen. sp. (l)	0.168	0.007	0.105
Pleistophora sp.	0.094	0.095	0.000
Phocanema decipiens (l)	0.088	0.005	0.005
Aporocotyle theragrae	0.035	0.004	0.004
Hysterothylacium aduncum (l)	0.013	0.015	0.049
Grillotia heptanchi (p)	0.081	0.000	0.249
Prosorhynchoides basargini (m)	0.054	0.000	0.176

[a] m = metacercaria, p = plerocercoid, l = larva.

Table 4. Average total percentage of data vectors correctly classified for four stocks of walleye pollock. (No. data vectors in training set = 100, No. data vectors in evaluation set = 103, No. analyses = 10).

Classification technique	Recognition	Prediction
Multicategory linear discriminant analysis	58.1 ± 5.7[a]	45.2 ± 6.7
Bayesian classification	67.5 ± 5.4	48.7 ± 2.2
K - nearest neighbor analysis		
K = 3	52.7 ± 7.6	45.0 ± 4.0
K = 5	55.6 ± 7.1	47.2 ± 4.7
K = 7	55.7 ± 7.0	45.7 ± 4.4

[a] $\bar{X}$ ± SD

Table 5. Misclassification matrix for classification of walleye pollock by geographical locality using multicategory linear discriminant analysis (No. data vectors in training set = 100, No. data vectors in evaluation set = 103, No. analyses = 10).

True category	Computed category			
	Strait of Georgia	West coast Vancouver Island	Queen Charlotte Sound	Dixon Entrance
Strait of Georgia	14.3 ± 2.6[a]	3.6 ± 2.5	0.3 ± 0.6	0.8 ± 1.0
	75.2 ± 13.9[b]	19.0 ± 12.9	1.6 ± 3.4	4.2 ± 5.2
West coast Vancouver Island	8.8 ± 3.8	9.4 ± 3.7	1.6 ± 1.5	1.2 ± 1.2
	41.9 ± 18.0	44.8 ± 17.8	7.6 ± 7.1	5.7 ± 5.9
Queen Charlotte Sound	7.6 ± 3.9	7.0 ± 5.1	15.1 ± 10.2	20.3 ± 9.8
	15.2 ± 7.7	14.0 ± 10.2	30.2 ± 20.4	40.6 ± 19.6
Dixon Entrance	1.2 ± 1.5	0.9 ± 0.9	3.1 ± 2.2	7.8 ± 3.0
	9.2 ± 11.3	6.9 ± 7.3	23.9 ± 16.7	60.0 ± 23.0

[a] Number of data vectors classified in category ($\bar{X}$ ± SD).

[b] Percentage of total data vectors classified in category ($\bar{X}$ ± SD).

Table 6. Results of the Kruskal-Wallis and STP tests for comparison of walleye pollock from four geographic localities (SG = Strait of Georgia, WC = west coast of Vancouver Island, QC = Queen Charlotte Sound, DE = Dixon Entrance).

	Prevalence		Abundance	
	H_{adj}	STP Summary	H_{adj}	STP Summary
Pleistophora sp.	11.100[b]	(SG,WC,QC,DE)[c]	-	
Aporocotyle theragrae	4.339		4.855	
Prosorhynchoides besargini (m)[a]	6.122		6.148	
Prosorhynchus sp. (m)	113.296[b]	(SG,WC)(QC,DE)	100.435[b]	(SG,WC)(QC,DE)
Rhipidocotyle sp. (m)	48.240[b]	(SG)(WC,QC,DE)	-	
Abothrium gadi	28.149[b]	(SG)(WC,QC,DE)	29.467[b]	(SG,WC)(WC,QC,DE)
Grillotia heptanchi (p)	5.547		5.568	
Nybelinia surmenicola (p)	63.260[b]	(SG)(WC,QC,DE)	82.250[b]	(SG)(WC,QC)(QC,DE)
Anisakis simplex (l)	3.000		56.704[b]	(SG,WC)(QC,DE)
Contracaecum-type B (l)	26.955[b]	(WC,SG,QC)(SG,QC,DE)	30.287[b]	(SG,WC,QC)(QC,DE)
Hysterothylacium aduncum (l)	9.693[b]	(SG,WC,QC,DE)	10.179[b]	(SG,WC,QC,DE)
Phocanema decipiens (l)	7.871[b]	(SG,WC,QC,DE)	8.935[b]	(SG,WC,QC,DE)
Spirurida gen. sp. (l)	23.987[b]	(QC,DE,SG)(DE,SG,WC)	24.986[b]	(SG,WC)(SG,QC,DE)

[a] m = metacercaria, p = plerocercoid, l = larva.

[b] Indicates significant heterogeniety among categories.

[c] Categories not significantly different ($p>0.05$) when contained within same set of brackets.

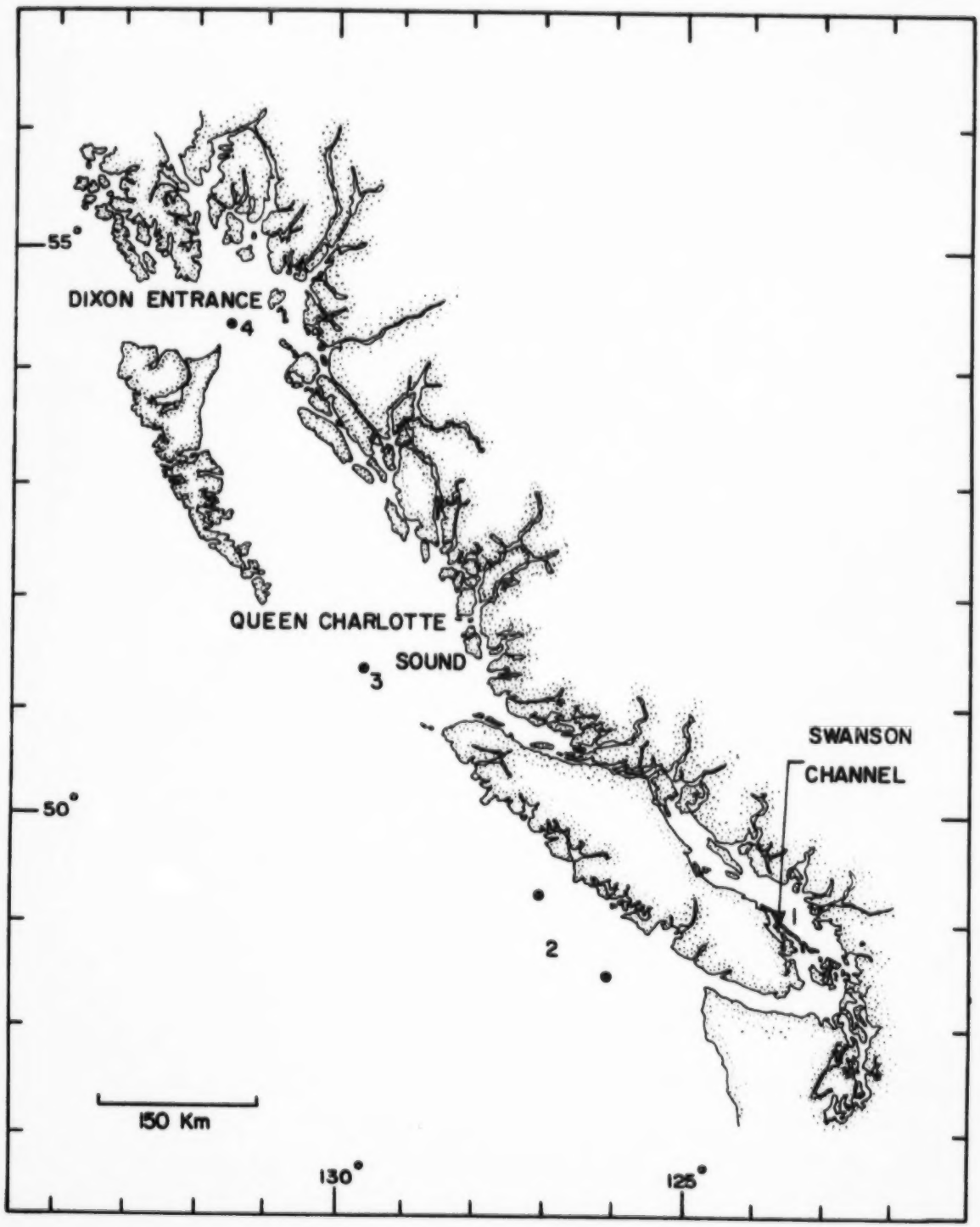

Fig. 1. Map of coastal British Columbia showing collection localities. (1. Swanson Channel, Strait of Georgia; 2. west coast of Vancouver Island; 3. southeastern Goose Island Grounds, Queen Charlotte Islands; 4. Dixon Entrance.)